Adult Feeding Behavior of *Lixophaga spenophori*, a Tachinid Parasite of the New Guinea Sugarcane Weevil[1]

John R. Leeper
UNIVERSITY OF HAWAII
HONOLULU, HAWAII

Shortly after the introduction of *Lixophaga sphenophori* (Villeneuve) (Fig. 1) into Hawaii, *Rhabdoscelus obscurus* (Boisduval) came under biological control. In the last twenty-five years, the extent of this control has decreased and this decrease is believed to be correlated with changes in the cultural practices used in sugarcane production (Beardsley, 1968).

One essential factor for most insect parasites is the food requirements of the non-parasitic stage. Without sufficient food sources, the adults' ability to survive and reproduce is reduced. Neglect of this principle in many cases has prevented parasites from being established and/or being able to exert economic control of their host. It is the purpose of this paper to discuss the adult feeding behavior of *L. sphenophori*.

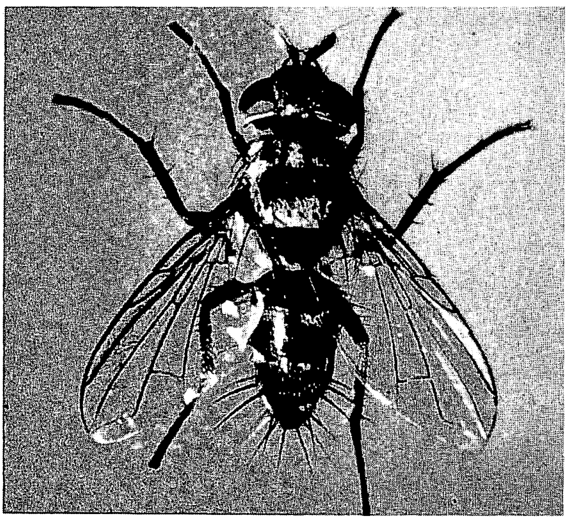

FIG. 1. *Lixophaga sphenophori*, male adult (6 mm.).

[1]A portion of a thesis submitted to the Graduate School of the University of Hawaii in partial fulfillment of the requirements for the Masters degree. Published with the approval of the Director of the Hawaii Agricultural Experiment Station as Journal Series No. 1586.

Field observations of the feeding behavior of adult *L. sphenophori* were made in sugarcane fields at Ewa, Oahu between June 1969 and June 1971. This area is relatively flat, about 23 m above sea level, and receives an average annual rainfall of about 52.6 cm (Fig. 2). Differences in elevation, exposure, topography, and climate might result in deviations from the habits observed.

Effects of Physical Factors on Feeding Behavior

Time of day was an important factor in the capture of *L. sphenophori* adults. Flies were in greatest numbers, most noticeable, and actively feeding between 8:30 and 10:30 AM. Bennett and Beg (1970) found the adults of the tachinid *Jaynesleskia jaynesi* Aldrich had a similar relationship of feeding and activity to the time of day. They found the flies were most numerous and fed frequently at flowers from 7:30 to 9:30 AM. These periods are conducive to fly activities because of favorable temperature and light intensity.

Illingworth (1914) noted that with caged *L. sphenophori* adults mating occurred in the bright early morning light. Muir and Swezey (1916) noted in Papua, New Guinea, mating occurred in the early morning and later in the day, the flies were seldom seen actively flying about. Illingworth (1914) also noted that with the increase in temperature, the

FIG. 2. Sugarcane fields at Ewa, Oahu showing herbicide sprayed irrigation ditch.

flies would retire to the shade of the sugarcane in the cages. Illingworth's observations for caged flies were confirmed and also found applicable to flies in the sugarcane fields.

Around 8:30 AM the flies sought bright, open places to rest. During the later part of the active period, the flies could be found in the more shaded areas. As the sunlight became more intense and the temperature increased, fewer flies could be found around the periphery of the sugarcane fields. *J. jaynesi* adults behave in a similar manner (Bennett and Beg, 1970). *L. sphenophori* adults probably return to the periphery of the sugarcane fields in the early evening with the return to lower temperatures and reduced light intensities.

If cages containing flies were kept in direct sunlight for extended periods of time, the flies would quickly die. Therefore, the cages were placed to utilize the bright early morning sunlight, but were protected from continuous direct exposure to the sun during the day.

Muir and Swezey (1916) stated that sugarcane can become infested with *R. obscurus* when the stalks are one to three feet tall. It is possible for *L. sphenophori* females to be present, seeking out weevil larvae, in a field of young sugarcane; but, fly activity may be restricted due to the lack of sufficient shade. Field observations support this. *L. sphenophori* adults were always more abundant around older, more dense sugarcane fields. Besides having more shade, the older fields tend to be more heavily infested with *R. obscurus,* which also favors the presence of the fly.

Weather conditions have an important influence on fly activity. Flies were most numerous and active on clear, sunny, light trade wind days and were scarcest and less active during the entire morning on overcast humid days. In contrast, Bennett and Beg (1970) noted that on overcast days when there was a heavy dew, *J. jaynesi* adults showed little activity until 8:00 AM, which represents only a half hour delay of activity. During light rain, *L. sphenophori* adults sought shelter and became less active. A similar response would be expected during heavy rains.

After locating a heavy concentration of *L. sphenophori* adults, they were relatively easy to capture for use in laboratory rearing, food source preference tests, and field sex ratio determinations. A honey-water mixture (100 ml. honey in 200 ml. water) was sprayed on the foliage and the flies were captured as they fed on the mixture. Early in the study, nets were used to capture flies; but they are easily injured. Because they are very docile, another method of capture was adopted. A glass vial was placed over a fly as it fed. One to four flies could be caught in a single vial before it was capped with a wad of cotton. The flies were released in a small cage (9.5 cu.in.) and taken back to the laboratory. Bennett and Beg (1970) used both nets and plastic vials to capture *J. jaynesi* adults. They found the net a more productive capture method later in the day. With vials, they captured as many as thirty or more flies per man hour. Using the same method, I could capture over seventy *L. sphenophori* adults per man hour.

FOOD SOURCES

Certain plants were found attractive as food sources for *L. sphenophori* adults. These plants were used as indicators of areas in which the flies might be found.

Gardner (1938) showed the relationship of the presence of food sources for the non-parasitic stage to host parasitization. The adult *Tiphia vernalis* Rohwer, a parasite of *Popillia japonica* Newman, feeds almost exclusively on the honeydew of aphids associated with certain plants. *T. vernalis* adults feed on honeydew in the morning and in the early afternoon drop to the ground in search of their host. Gardner found the degrees of parasitization and superparasitization were related to the distance of the host from the adult parasites' food source. The further the host was from the food source, the less the parasitization and superparasitization.

Drake (1920) suggested the use of *Crotalaria usaramoensis* as a trap crop in the control of *Nezara viridula* L. by the tachinid *Trichopoda pennipes* Fabricius. Drake stated that the floral nectars were attractive to the adult parasite as a food source and the pods were attractive to the stink bug. Therefore, both the parasite and its host would be drawn to a common area which would in turn increase the percent parasitization. Growing *Crotalaria* spp. as a trap crop is a recommended control measure, to be used in conjunction with *T. pennipes*, in Hawaii's macadamia nut orchards (Mitchell, 1971).

The relationships of food sources to parasitization indicate that the availability of the adult food can have a major bearing on the effectiveness of the species as a parasite. Therefore, a study was made to determine the food sources of the adult *L. sphenophori*.

L. sphenophori adults were occasionally observed feeding on mealybug honeydew and on sap from broken and cut sugarcane stalks, but neither of these were felt to be principal food sources for the flies. Flies were also observed feeding on dew which probably was their primary source of water, but it, of course, lacks the nutrients required by the flies. The nutrients required by *L. sphenophori* are derived primarily from nectars produced by certain weeds.

Williams (1931) observed *L. sphenophori* adults feeding at the flowers of a small *Euphorbia* weed growing alongside a sugarcane field. Two *Euphorbia* spp. were common in the sugarcane fields. They were *Euphorbia glomerifera* (Millsp.) L.C. Wheeler and *E. hirta L. Phyllanthus niruri* L., another small euphorb, was also found in these fields. These weeds commonly grew in and alongside irrigation ditches that run through the sugarcane fields.

In the morning, the flies could regularly be observed feeding at the flower heads of *E. hirta*. Occasionally they were observed feeding at the flower heads of *E. glomerifera*, but were never seen feeding on *P. niruri*. These weed species were grown in trays and placed in cages with *L. sphenophori* adults. The flies favored *E. hirta* when provided with a choice. The adults were never observed feeding on *P. niruri*, even when it was the only weed present.

The inflorescences of *P. niruri* are located singly on the underside of the leaf axils. The inflorescences of *E. glomerifera* and *E. hirta* are located in clusters, on stalks, arising from leaf axils. The corolla of a *P. niruri* flower consists of six whitish petals, each with a longitudinal green stripe. The corolla of an *E. glomerifera* flower consists of four, very small, pinkish-white petals. A single minute floral gland is located at the inner base of each petal of both weeds. The six glands on *P. niruri* are well protected by the petals while the four glands on *E. glomerifera* are exposed. The flowers of *E. hirta* lack petals but each has four exposed glands (Fig. 3). It is believed that *L. sphenophori* adults will not feed on *P. niruri* due to the awkward positioning of the flowers and the protection given the floral glands by the petals. *L. sphenophori* adults stand on the flower heads of *E. glomerifera* and *E. hirta* while feeding.

Another euphorb, *Ricinus communis* L., castor bean, was found attractive to *L. sphenophori* adults as a food source. These grow mainly in

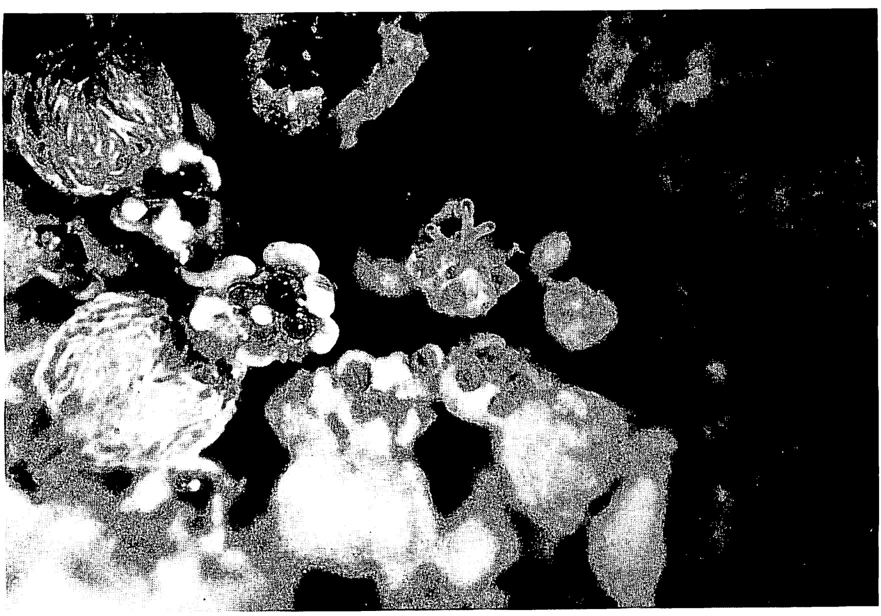

FIG. 3. Close-up of *Euphorbia hirta* floral nectaries.

areas not cultivated in sugarcane and can grow into plants standing over eight feet high. The flies are attracted to nectars produced by extrafloral nectary glands located along the petiole and at the bases of flower axils. Flies were observed feeding at the glands on petioles. One or two extrafloral nectary glands are located at the base of each petiole near the axil; two additional glands are located singly, a few inches apart, further up the petiole; and one or two glands are located on the petiole just behind the leaf. Flies were never observed feeding at the extrafloral nectaries located at the bases of flower axis. The flowers are placed tightly together and prevent access of the flies to these glands.

Desmanthus virgatus (L.) Willd., a legume, is common in the sugarcane fields and has conspicuous, shiny red, extrafloral nectary glands. These glands are located singly on the petiole between the lower pair of bipinnate leaves. Ants, other Hymenoptera and adult Coleoptera were regularly observed feeding on the nectars from the extrafloral glands of *D. virgatus. L. sphenophori* adults were never observed feeding on the nectars of this plant. Plants were grown at the laboratory and placed in cages with the flies. In the early morning, nectar droplets were observed on the extrafloral glands, but the flies would not feed on them. Eventually, the flies became so weak that they would remain stationary on a finger and could have their mouth parts placed on the nectar droplets. Only then were the flies observed feeding on the nectars. The petioles and bipinnate leaves of *D. virgatus* give poor footing for the flies and may be why they do not ordinarily feed on the nectars.

Other weeds, reported as food source plants of tachinids, were studied to determine their usefulness as food source plants. The plants were grown at the laboratory and then placed in cages with *L. sphenophori* adults.

C. usaramoensis flowers were mentioned earlier as producing nectars which *T. pennipes* feed upon. That species was not available, but *Crotalaria incana* L. and *Crotalaria mucronata* Desv. were grown for study. *Crotalaria* flowers are papilionate and the floral nectars are inaccessible to *L. sphenophori* adults. However, both *C. incana* and *C. mucronata* have extrafloral nectary glands located at the base of the pedicels near the main flower stalk and on the axis at the axils of the younger leaves and branches (Fig. 4). Unlike the conspicuous extrafloral nectary glands of *R. communis* and *D. virgatus*, the extrafloral nectary glands of *C. incana* and *C. mucronata* are inconspicuous except when nectar is present as droplets on hairs at the location of the glands.

When either *Crotalaria* spp. was placed in cages containing *L. sphenophori* adults, the flies were immediately attracted to the nectars. A single *C. incana* plant was found growing in the sugarcane fields across the road from a stand of *R. communis* where flies were regularly collected. The plant was in an irrigation ditch, in good growing condition, producing new growth, flowers, and seeds. The plant was examined on many occasions, but nectar droplets were never observed. Ants were always present on the plant, but other insects were never seen feeding on it.

Bennett and Beg (1970), in discussing the habits of *J. jaynesi* adults listed several weeds as food sources. Flies were noted to feed on the flowers of *Lippia nodiflora* and *Stachytarpheta* spp. (both Verbenaceae), *Euphorbia* spp., and *Bidens* spp. and *Cosmos* spp. (both Compositae). Of these, only the euphorbias were common in the sugarcane fields and have already been discussed. No *Lippia* spp. were found. Flower stalks of *Stachytarpheta urticaefolia* (Salisb.) Sims were placed with caged flies and found not to be attractive. *Stachytarpheta* spp. were not found in the Ewa Sugar Company fields and were not studied as possible food sources for the flies because they have been declared noxious for Hawaii State land leases (Haselwood and Motter, 1966). Fresh cuttings of *Bidens pilosa* L. were placed in cages with *L. sphenophori* adults, but the flies were not attracted to them.

Sex Ratio of Flies Collected on Food Source Plants

The sex ratio of *L. sphenophori* was determined by recording the sexes of 1,365 laboratory-reared flies which emerged between 13 October 1970, and 22 January 1971. There were 694 males and 671 females,

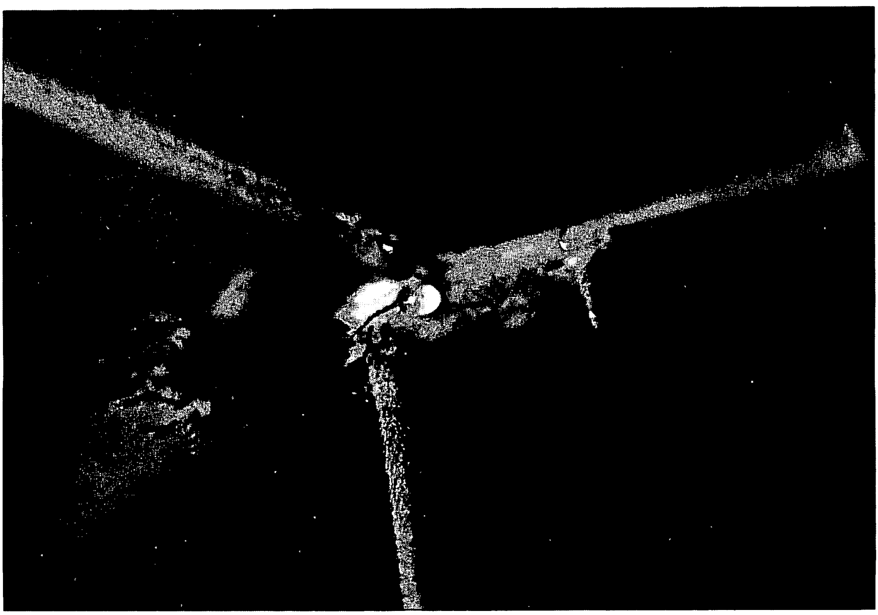

FIG. 4. Close-up of nectars exuding from extrafloral nectary glands of *Crotalaria incana*.

giving a sex ratio of 1.034:1. A chi-square test indicated that there was no significant difference between the expected (1:1) and the observed sex ratios of newly emerged laboratory-reared flies. There were, however, significant differences from the 1:1 sex ratio in the flies caught on food plants in the sugarcane fields. There were also significant differences in the sex ratios of the flies caught on the two plants.

A total of 797 *L. sphenophori* adults were captured on *E. hirta* between 23 July 1969, and 15 October 1970. Of these, 573 were males and 224 were females, giving a sex ratio of 2.6 males captured for each female. The calculated chi-square value of 152 represents a significant difference at the 0.001 confidence level.

A total of 1,254 *L. sphenophori* adults were captured on *R. communis* between 4 August 1970 and 7 January 1971. Of these, 981 were males and 273 were females, giving a sex ratio of 3.6 males captured for each female. The calculated chi-square value of 399 was again highly significant. Therefore, a highly significant larger number of males than females were captured on the food plants. One possibility was that a greater proportion of the gravid female flies remained in the sugarcane stand in search of their host. If this was so, there should have been a significantly fewer number of gravid females remaining on the food plants. Dissections of captured females indicated that this explanation was not valid.

A comparison of the sex ratio of the flies captured on the two food source plants yielded a highly significant chi-square value of 10.3. There was a significantly greater ratio of males to females among flies caught on *R. communis* than on *E. hirta.* Two explanations for the differences in sex ratios appear possible. Perhaps there are differences in the amount or kind of attractive substances present in the plants. The differences in sex ratios may reflect quantitative or qualitative differences in the substances that attract the flies. Another possible explanation could be that these ratios reflect differences in the behavior patterns of the two sexes. The *E. hirta* plants were growing in the irrigation ditches that ran through the sugarcane fields proper and were virtually surrounded by the sugarcane. The *R. communis* plants were growing across a road from the sugarcane. With a greater distance from and less involvement with the sugarcane, a greater proportion of male flies and an even smaller proportion of gravid female flies might be expected to leave the sugarcane field.

Discussion

The observations on food source plants of adult *L. sphenophori* made in the sugarcane fields and in the laboratory showed two weeds, *E. hirta* and *R. communis,* to be of primary importance. *E. hirta* is a relatively low growing weed and could be grown in the irrigation ditches without clogging them. *R. communis* is a large plant and its size would restrict its growth to areas outside the sugarcane fields proper. It is believed that *C. incana* and *C. mucronata* would also make excellent food source plants for flies in the field although the *C. incana* plant growing in the sugarcane field was never observed to have *L. sphenophori* adults feeding on it. Since there was only a single plant, it may have been overlooked by the flies. The two crotalarias stand about three feet high and could clog irrigation ditches if allowed to grow there. However, they could be grown next to the ditches and along the borders of the sugarcane fields.

Allowing weeds to grow in and around cultivated fields has been thought to be a poor cultural practice. If recognized food source plants of adult insect parasites are to be utilized for the benefit of the parasite, this attitude will have to be changed. If the plants are cultivated or allowed to grow naturally, criteria will have to be set as to where and to what extent they will be grown.

Economics is an important consideration in deciding whether to allow certain weeds to grow or not. There are going to be weeds present that are detrimental or of no value to sugarcane production. These weeds will always be eradicated. Due to increased costs, cheaper methods, which are non-selective, are replacing manual methods of weed control.

An additional comment on the use of herbicides should be made. After areas, where large numbers of *L. sphenophori* adults had previously been seen, were sprayed with herbicides there was always a noticeable drop in the number of flies. This could be due to the flies leaving the area or to the toxic effects of the herbicides or both. Simple, preliminary toxicity tests were conducted to determine the effects of selected herbicides on the flies. The herbicides tested, at 1000 ppmw, for toxicity to *L. sphenophori* adults were: Ametryne (2-ethylamino-4-isopropylamino-6-methylthio-s-triazine), Dalapon, sodium salt (sodium-2, 2-dichloropropionate); 2, 4-D (2,4-dicholorophenoxyacetic acid); Diuron (3-(3,4-dichlorophenyl)-1, 1-dimethylurea); and MSMA and (monosodium acid methanearsonate). The tests showed possible toxicity by all the herbicides except Diuron. Research has shown the toxicity of certain herbicides to honey bees (Morton, Moffett, and Macdonald, 1972; and Morton, and Moffett, 1972). Similar in-depth studies should be conducted on *L. sphenophori*.

BIBLIOGRAPHY

Beardsley, J.W. 1968. A proposal for research on sugarcane insects; evaluation and augmentation of natural enemies of sugarcane pests in Hawaii. Paper submitted to H.S.P.A. Unpublished.

Bennett, F.D. and M.N. Beg. 1970. Report on a visit to the Cauca Valley, Colombia to collect *Jaynesleskia jaynesi* (Tachinidae), a parasite of *Diatraea* spp. May 1970. *Report, Commonwealth Institute of Biological Control.* West Indian Station, Curepe, Trinidad:13.

Drake, C.J. 1920. The southern green stink-bug, *Nezara viridula.* Quarterly Bulletin State Plant Board, Florida, 4: 1-75.

Gardner, T.R. 1938. Influences of feeding habits of *Tiphia vernalis* on the parasitization of the Japanese beetle. *J. Econ. Entomol.* 31: 204-207.

Haselwood, E.L. and G.G. Motter, ed. 1966. *Handbook of Hawaiian Weeds.* Institute for Technical Interchange. East-West Center. 479 pp.

Illingworth, J.F. 1914. Further notes on the breeding of the Tachinid fly, parasite on the cane beetle borer. *J. Econ. Entomol.* **7**: 390-398.

Mitchell, W.C. 1971. Use of *Crotalaria* spp. in macadamia nut orchards. Personal Communication. University of Hawaii, Honolulu, Hawaii.

Morton, H.L. and J.O. Moffett. 1972. Ovicidal and larvicidal effects of certain herbicides on honey bees. *Environ. Entomol.* **I**: 611-614.

Morton, H.L., J.O. Moffett, and R.H. Macdonald. 1972. Toxicity of herbicides to newly emerged honey bees. *Environ. Entomol.* **I**: 102-104.

Muir, F. and O.H. Swezey. 1916. The cane borer beetle in Hawaii and its control by natural enemies. Report of work of the Experiment Station of the Hawaiian Sugar Planters' Association. *Hawaiian Sugar Planters Assoc. Bull.* **8** Entomological Series: 5-45.

Snedecor, G.W. and W.G. Cochran. 1969. *Statistical Methods.* Iowa State University Press, Ames, Iowa. 593 pp.

Williams, F.X. 1931. *Insects and Other Invertebrates of Hawaiian Sugar Cane Fields.* Hawaiian Sugar Planters Assoc., Honolulu, Hawaii.

Wolcott, G.N. 1942. The requirements of parasites for more than hosts. *Science.* **96**: 317-318.